

EXTENDED REVERSE SUPERFICIAL SURAL ARTERY FLAPS - A CLINICAL STUDY

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CERTIFICATE

*This is to certify that, this dissertation titled “**EXTENDED
REVERSE SUPERFICIAL SURAL ARTERY FLAPS - A CLINICAL STUDY**”
submitted by **Dr. RAGU. A**, appearing for M.Ch (Plastic Surgery)
degree examination in August 2007 is a bonafide record of work
done by him under my guidance and supervision.*

Prof. M.P. NAMASIVAYAM, M.S., M.Ch.,
Professor and Head,
Department of Plastic, Reconstructive &
Facio - Maxillary Surgery,
Madras Medical College,
Chennai - 600 003.

DEAN,
Madras Medical College,
Chennai - 600 003.

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CONTENTS

SL.NO	TOPIC	PAGE NO
1.	Introduction	1
2.	Aim of the Study	3
3.	Materials & Methods	4
4.	Review of Literature	7
5.	Vascular Anatomy	18
6.	Flap Marking & Operative Technique	24
7.	Observation	35
8.	Discussion	41
9.	Conclusion	49
10.	Bibliography	
11.	Proforma	
12.	Master Chart	

INTRODUCTION

Skin defects over the lower third leg, ankle , heel and foot areas were always a challenging task to a reconstructive surgeon, since these areas are difficult to cover. These areas are easily susceptible to trauma and are the site of numerous trophic problems like pressure sores, chronic ulcers and penetrating injuries. The possibilities for coverage of such defects are few and those that exist have complications. The flap chosen should be easy to execute quickly with minimal discomfort to the patient and should provide durable coverage for the defect.

Many studies have proven beyond doubt the versatility and reliability of the reverse superficial sural artery fascio-cutaneous flaps in covering these defects^{13,15,31,39,46,22,30,48,50,51} and a few studies have even concluded that the reverse sural flap is the flap of choice in covering defects of lower third of leg, foot, ankle and heel regardless of the local conditions^{36,46,47,48,49,50,51}.

However, in many occasions, conventional reverse sural flaps limited to middle third of leg, falls short of the critical area to be covered, with the limitation being the location of the flap (middle third of leg).

Extending the flap territory proximally into the upper third of the leg would have a versatile flap with immense potential. Nevertheless, the critical questions remained “How far?” and “How safe?” for which very little references exist in literature albeit with a very limited number of cases^{47,49}.

AIM OF THE STUDY

- To study the versatility, reliability and safety of the extended reverse superficial sural artery fascio cutaneous flaps in covering the lower third leg, ankle, heel and foot defects.
- To refine the surgical techniques with regard to safe elevation of large flap dimensions and possible extension of territory in the light of proper understanding of relevant applied anatomy to ensure a reliable flap.
- To compare the conventional method of flap markings and operative technique with a modified method of flap markings and operative technique with regard to the reliability and flap survival.

MATERIALS AND METHODS

This study was done in our department from March 2005 to April 2007. This is a prospective comparative study of the reverse sural artery fasciocutaneous flaps, most of them with extensions into the upper third of leg done by conventional markings and method and modified markings and method which evolved as we were analysing the causes for failure of the extended segments done by conventional method.

A total number of 26 patients were included in this study with soft tissue defects exposing tendons or bone in the lower third of leg, malleolar area, tendo achilles area, heel, hind foot and dorsum of the foot due to various aetiologies. As the modified markings and method were evolved as we were analysing the failure in our initial cases, randomisation of cases could not be done. Hence, initial 13 cases were done by the conventional method and subsequent 13 cases were done by the modified method.

In an effort to minimize the bias, the same team of surgeons operated in all the 26 cases. Equal number (2 cases) of cases with flaps confined to middle third of leg were used as control in both groups. As far as possible, the cases with same aetiologies and similar flap dimensions were taken for comparison in both groups.

INCLUSION CRITERIA

- Patients within the age group of 10 years to 60 years.
- Patient with soft tissue defects in the lower third of leg, malleolar area, tendoachilles area, heel, hind foot and dorsum of foot due to following aetiologies were included in the study.
 1. Motor vehicle accidents
 2. Closet injury
 3. Wheel spokes injury
 4. Unstable scar
 5. Malignant melanoma and other malignancies

6. Electrical burns
 7. Industrial accidents
 8. Osteomyelitis
- Patient with co-morbid conditions like Diabetes mellitus, hypertension and coronary artery diseases were not excluded from the study.

EXCLUSION CRITERIA:

- Patients with age less than 10 years and more than 60 years.
- Patients with diabetic ulcers, venous ulcers, neuropathic and trophic ulcers were excluded from the study.

REVIEW OF LITERATURE

The foundations, of flaps based on the superficial sural artery was laid by Donski and Fogdestam who were the first to describe the flap in 1983, Le Hearse et. al., (1988) published their paper titled, “Anatomic basis of the sural facio-cutaneous flap- surgical application”. In this paper, the authors reported on their anatomic study of 15 dissections, perforating pedicles originating from the peroneal artery (3 to 5) and posterior tibial artery (4 to 5) destined for the skin and fascia of the posterior aspect of the leg were constantly found. This study suggested the possibility of a distally based sural fascio cutaneous flap, a flap which has been successfully constructed clinically.

Satoh et al (1989)²⁷ used the direct sural fasciocutaneous flap in lower leg reconstruction in 17 clinical cases as pedicled, island and free flaps. Similarly Le Huec et al (1990) described their experience with the lateral sural cutaneous artery island flap in the treatments of lower leg defects.

The paper “skin island flaps supplied by the vascular axis of the sensitive superficial nerves anatomic study and experience in the leg”, was presented by Masquelat et al (1992)²⁰. They showed that

the vascular axis accompanying the superficial sural nerve gives off sural cutaneous branches in the suprafascial course of the nerve, and anastomosed with the septocutaneous arteries arising from a deep main vessel. Thus the concept of a neuroskin island flap was developed and applied to clinical cases for coverage of defect in the leg.

Hyakusoku et al (1994)¹⁵ reported their experience with heel coverage with a T shaped distally based sural island fasciocutaneous flap. In two cases, they put forth the following arguments in the support of the distally based superficial sural artery flap.

1. It does not sacrifice any major arteries of the leg.
2. It covers the whole calcaneal area with a one stage operation.
3. It can be elevated without losing any nerve sensitisation of the leg.
4. The donor site can be closed primarily when the flap is small enough.

Hasegawa et al (1994)¹³ applied the distally based superficial sural artery flap in 21 cases and reported survival of all flaps. Most

flaps showed signs of venous congestion. In the largest flap (10 cm x 13 cm) edema lasted 2 months. In the flap whose pedicle was raised without the deep fascia, there was necrosis at the distal tip of the flap.

An anatomical study of the reverse flow lateral sural cutaneous artery island flap was carried by Li and Li (1995)⁴². The circulatory patterns of skin flaps were studied by microsurgical dissection, dye injection and angiography in 50 lower legs of fresh cadavers. The conclusions were as follows:

1. The lateral sural cutaneous artery descends constantly and superficially accompanied by concomitant nerves. The upper posterolateral area of the lower leg is the best donor site of the flap.
2. The lateral sural artery and the peroneal perforating artery form an anastomotic arcus around the lateral malleolus in 88.6% of the lower legs. The mean diameter of the anastomotic arcus is 0.63 1- 0.19 mm.
3. The peroneal perforating vessel is 3.5 +/- in length. Based on it, the pedicle of the flap can be prolonged 6-8

cm on the main vessel of the lateral sural cutaneous artery.

4. Creation of the flap has no influence to the blood supply and function of the lower leg.
5. By antegrade transfer, the lateral sural island flap could be used to repair the defects around the knee and upper tibia. However retrograde transfer of the flap has a higher clinical value in repairing the defects on the lower one third of the lower leg and medial malleolus.

In 1995 Oberlin et al⁴⁶ reported 14 cases in which they had performed distally based sural neurocutaneous flap. Rajacic et al (1996)²⁵ presented their experience with this flap in 21 patients. They said that although the flap was described as reliable for covering defects around the ankle joint, they were able to cover defects of the dorsum of the foot distally and upto the middle third of the tibia proximally.

Jeng et al (1997)³⁹ published their article on distally based sural island flap for foot and ankle reconstruction. Three variants of this flap were used in 19 patients. Four adipofascial sural flaps were used to cover the exposed Achilles tendons. Fasciocutaneous sural

flaps were used to resurface defects in the ankle region as well as the non weight-bearing area of the heel. Another four flaps were used to resurface the weight bearing areas of the heel. All flaps did well. According to them this flap has the potential for re-innervation.

A modification of the reverse sural artery flap was described by Chang-Keng et al³¹ in 1997. According to them, the pedicle of the reverse sural artery congestion and peripheral arterial insufficiency occurred when the flap is transferred subcutaneously. Their modification consisted of a wider pedicle during flap design and transferred it without passing the flap through a subcutaneous tunnel. The pedicle is then divided in a second operation. They applied this modification in four patients and reported satisfactory results.

Yilmaz et al (1998)³⁰ similarly described their modification In which they left a skin extension over the fascio vascular pedicle and used it as a roof of the tunnel.

Nakajima et al (1999)²² reported their series of 23 cases of various reconstruction of the lower leg using this flap. The survival of the flap in their hands was extremely good.

Imanshi et al (1999)³⁸ presented their papers titled, “venous drainage of the distally based lesser saphenous sural veno

neuroadipofascial pedicled fascio-cutaneous flap a radiographic perfusion study". In this paper, the drainage pathway of the distally based lesser saphenous-sural veno-neuroadipofascial pedicled fasciocutaneous flap using accompanying arteries of the lesser saphenous vein and sural nerve as nutrient vessels of the flap was radiographically investigated using five fresh cadavers. Small long veins existed along the lesser saphenous vein and they were considered to be the concomitant veins of the accompanying arteries of the lesser saphenous vein.

They anastomosed with the lesser saphenous vein in some places and played a role in bypassing valves in the lesser saphenous vein.

The salvage of the distal foot using the distally based sural island flap was described by Jeng et al (1999)³⁹. The authors described their additional experience with the distally based sural island flap for reconstruction of the whole foot, including the forefoot area in 8 patients.

The skin flap, they said, can be elevated in all parts of the sural region, this modification allowed a further reach of the flap for coverage of the distal foot and sole. All flaps innervated by the lateral sural cutaneous nerves, were able to provide protective sensation in the distal soles. In 7 patients, the flaps survived completely, and only 1 patient had partial necrosis of the flap.

Gupta et al (1999)³⁶ have described the results of the distally based superficial sural artery flap in 12 cases and stated this as their flap of choice for reconstructive surgery of lower one third of leg, calcaneal area and malleoli.

Isenberg (2000)³⁷ in his article “The reverse sural artery neurocutaneous island flap in composite lower extremity wound reconstruction” presented the use of this flap in a patient cohort 65 years of age or older with high prevalence of diabetes and peripheral vascular diseases. He reported reliability of the flap even in this group.

Touam et al (2000)⁴⁶ in their comparative study of two series of distally based fasciocutaneous flaps for coverage of the lower one fourth of the leg, ankle & foot, in which they did 27 lateral supramallolar flaps and 42 distally based sural neurocutaneous flaps, concluded.

- 1) Distally based sural neuro cutaneous flaps were very reliable, regardless of the local conditions.
- 2) Flap is indicated even after the failure of other flaps.
- 3) Used safely in emergency set up.
- 4) Flap of choice covering defects over the foot, ankle and heel regardless of the local terrain.
- 5) Flap offers the possibility of successfully covering extensive defects, easy to execute and has limited aesthetic and functional sequelae.

In their study, the proximal limit of the flap is approximately 20 cms above the tip of lateral malleolus which roughly corresponds to the junction of middle and upper thirds of leg.

C.H. Hsieh et al (2005)⁴⁸ in their case report of a distally based sural island flap for the reconstruction of a large - soft tissue defect in an open-tibial fracture with occluded anterior and posterior arteries, has reported a large flap of 10x16cms elevated safely based on only one peroneal perforator.

In 2002, Ayyappan T et al⁴⁷ from Gujarat reported 5 cases of super sural neurofasciocutaneous flaps in acute traumatic heel reconstruction. On the basis of pre-existing anatomic studies, they developed the possibility of using distally based neuro-skin flaps of huge dimensions that extend well beyond conventional confines. The versatility of this extended, reversed neuro-fasciocutaneous flaps in regard to its reliability and safely despite its huge dimensions is commendable.

Ulrich Kneser, M.D., et al (2005)⁴⁹ successfully used delayed sural flaps based on a two-step procedure for the treatment of 11 patients. They concluded that the delay procedure positively affects the viability of large sural neuro fasciocutaneous flaps. The authors recommend this modification for patients with large defects at the distal third of the lower leg foot, requiring a two-step surgical approach due to the underlying disease.

Shao-Liang Chen et al⁵⁰ in 2006 described a distally based sural fasciomusculocutaneous flap including the sural nerve and a midline cuff of the gastrocnemius muscle to cover wounds located over middle or distal portion of the foot. The flap is designed on the proximal third of the posterior calf and is nourished in a retrograde manner by the lower peroneal septocutaneous perforators, through the vascular axis of sural nerve to the musculocutaneous perforators of the gastrocnemius muscle. This flap is very useful for foot reconstruction, because of its long vascular pedicle and the availability of the skin portion of the proximal calf based on direct branches between the musculocutaneous perforators and the neurovascular axis of the sural nerve.

Akthar S. et al (2006)⁵¹ in their large series of 84 patients, evaluated the efficacy of reverse sural artery fasciocutaneous flap for coverage of lower third leg, posterior heel, malleoli and hind foot. The dimension of the flap ranged from 5 to 15 cm in length and 4 to 12 cm in width post-operatively 66 flaps survived completely while marginal necrosis was seen in six patients and infection in four patients. The complete flap necrosis occurred in eight patients. There was no considerable morbidity at donor site and all patients had satisfactory outcome.

They concluded that

- The distally based superficial sural artery flap is a versatile, reliable procedure, useful in reconstruction of lower third leg, heel, malleoli and hind foot defects.
- The surgical technique is safe, of short duration and provides alternative to microsurgical reconstruction.

VASCULAR ANATOMY OF THE SUPERFICIAL SURAL ARTERY FLAP

The cutaneous blood supply of the posterior calf is by musculo-cutaneous perforators from gastrocnemius muscle in the upper half and superficial sural cutaneous arterial system in the lower half of the posterior calf.

The medial head of gastrocnemius is better developed than the lateral head and the medial sural artery is therefore usually slightly greater in diameter than the lateral. Within each head of the muscle, each artery divides into two or three longitudinally running branches. The lateral sural artery may give off superficial sural cutaneous branch. One artery always accompanies the medial sural cutaneous nerve and one artery may run with the lateral sural cutaneous nerve and its peroneal communicating branches. The cutaneous artery in the mid-line between the two heads of gastrocnemius initially lies beneath the deep fascia in the company of medial sural cutaneous nerve. It may run along with the nerve or pierce the deep fascia to join the short saphenous vein.

The vessel running in the mid line between the heads of gastrocnemius was named by *Manchot* as *arteria suralis superficialis media* and by *Adachi* & others as *arteria saphena parva*. It is currently unrecognised in *Nomina Anatomica* and will be referred to as the median superficial sural artery although another possible name for it might be small saphenous artery. It arises from the popliteal artery (48%), from lateral sural artery (39%) or from one of the inferior genicular arteries (13%). The artery courses posteriorly for 2 to 3 cms before joining the medial sural nerve, descending between the two heads of the gastrocnemius muscle. It follows the lateral edge of Achilles tendon.

After its origin in the popliteal fossa, the median superficial sural artery runs subfascially between the two heads of the gastrocnemius and pierces the deep fascia at the junction of upper and middle thirds of the leg in the posterior mid line and runs distally suprafascially in the lower two-thirds of the leg accompanying the medial sural cutaneous nerve and the short saphenous vein. The artery courses alongside the sural nerve to the distal one-third of the leg, either terminating or anastomosing with the supramalleolar branch of the peroneal artery and posterior tibial artery. Rare instances have been recorded in which this vessel was so well developed that it

continued all the way down to the foot and communicated with the lateral tarsal artery. This artery gives off lots of arteria nervosum to the nerve with septocutaneous perforators. Usually paired venae comitantes travel with the median superficial sural artery.

The median superficial sural artery which runs in conjunction with the medial sural cutaneous nerve and a series of two arteries accompanying the lesser saphenous vein provide the axial pattern blood flow to the suprafascial plexus, subcutaneous vascular plexus and subdermal plexus which allows elevation of this flap. These axial pattern vessels make a series of interconnections with perforating vessels in the region of the lateral malleolus.

The sural artery will on occasion form a vascular connection to the lateral tarsal artery, which emanates from the anterior tibial vessel.

In addition a series of four to five fasciocutaneous perforators from the peroneal artery travel in the crural septum to supply the skin of the lateral leg. These fascio cutaneous perforators are the vascular supply of the fibula osteocutaneous flap skin island. They also form inter communications with the axial pattern arteries that accompany the medial sural cutaneous nerve. These vessels typically are located in the posterior crural septum, starting at a point 5cm

above the tip of the lateral malleolus and extending proximally to a distance of approximately 13cm above the lateral malleolus.

Therefore a rich plexus of fasciocutaneous and musculocutaneous perforators localized to the lateral aspect of the distal third of the leg that communicate with a series of axial patterned vessels accompanying the sural artery and lesser saphenous vein provide the principal blood supply to the suprafascial plexus, subcutaneous plexus and subdermal plexus along the posterior calf. The distally based sural fasciocutaneous flap should therefore be designed to incorporate these structures in an effort to maximize local blood flow. Venous drainage is ensured by a network of vessels that is included in the pedicle even when it is not possible to include the short saphenous vein.

Approximately four to eight fasciocutaneous perforators arising from the peroneal artery and venae comitantes follow the course of the posterior intermuscular septum to supply the crural fascia and skin. After penetrating the crural fascia, they give rise to several branches that communicate with adjacent perforators, forming an interconnecting vascular plexus on the crural fascia. The plexus extends from the posterior margin of the lateral malleolus to the superior part of the leg.

Multiple communications exist between this fascial network and superficial sural artery and the overlying subcutaneous and subdermal plexuses. The connections between the septocutaneous vessels form a rich suprafascial plexus with longitudinally oriented arcades. In the lower two-thirds of the leg, the posterolateral septal perforators originating from the peroneal artery emerge between the flexor hallucis longus and soleus at one side of the septum and peroneus brevis at the other. The widest fasciocutaneous perforators are close to the distal and proximal areas.

The medial sural nerve descends in close association with the lesser saphenous vein, passing posterior to the lateral malleolus to supply the lateral side of the foot and fifth toe. This nerve is supplied by the median superficial sural artery in the proximal onethird of the leg. The distal two-thirds of the nerve is supplied by fasciocutaneous branches of the peroneal artery. These branches course along the upper surface of the crural fascia for a variable distance before supplying the nerve; consequently, a longitudinal strip of fascia must be harvested with the nerve. In addition, the sural nerve has also intrinsic blood supply.

The intrinsic system consists of epineural, perineural, and endoneural vessels, longitudinally oriented with multiple levels of communication. This system has a connection with the median superficial sural artery and fasciocutaneous branches of the peroneal artery.

The lesser saphenous vein takes its origin from the lateral extension of the dorsal venous arch of the foot. It passes posteriorly to the lateral malleolus accompanied by the sural nerve. At the junction of the distal and middle thirds of the leg, the lesser saphenous vein locates more medially and follows the course of the sural nerve.

FLAP MARKING

THE COURSE OF THE SURAL NERVE

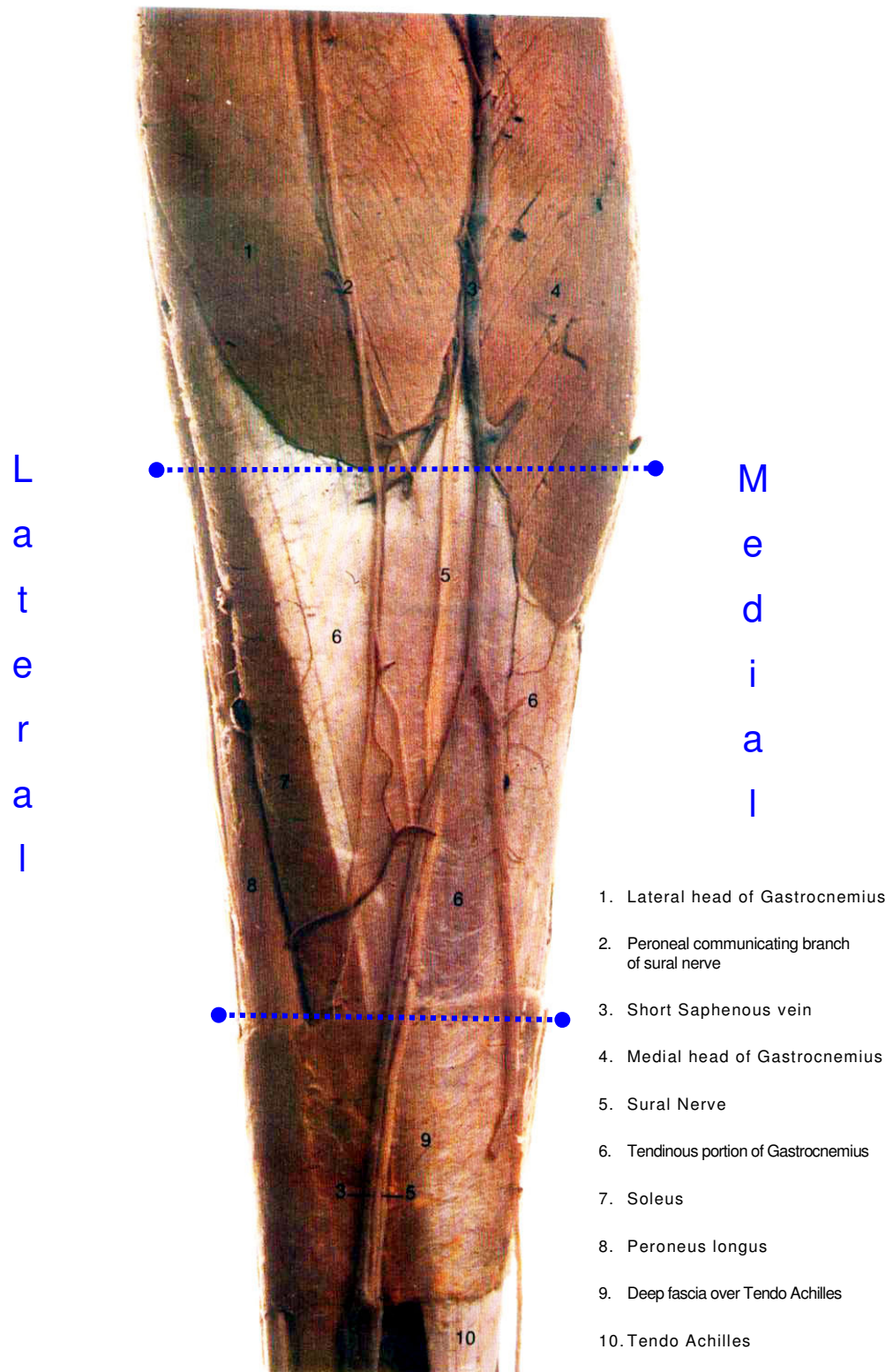
The course of medial sural cutaneous nerve and its accompanying median superficial sural vessels in the leg is conveniently described by dividing the leg into three segments.

Upper third: Posterior mid-line of leg deep between the two bellies of gastrocnemius.

Middle third: Runs suprafascially in the posterior mid-line.

Lower third: Runs suprafascially from posterior mid-line to the mid point between the lateral border of TendoAchilles and tip of lateral malleolus.

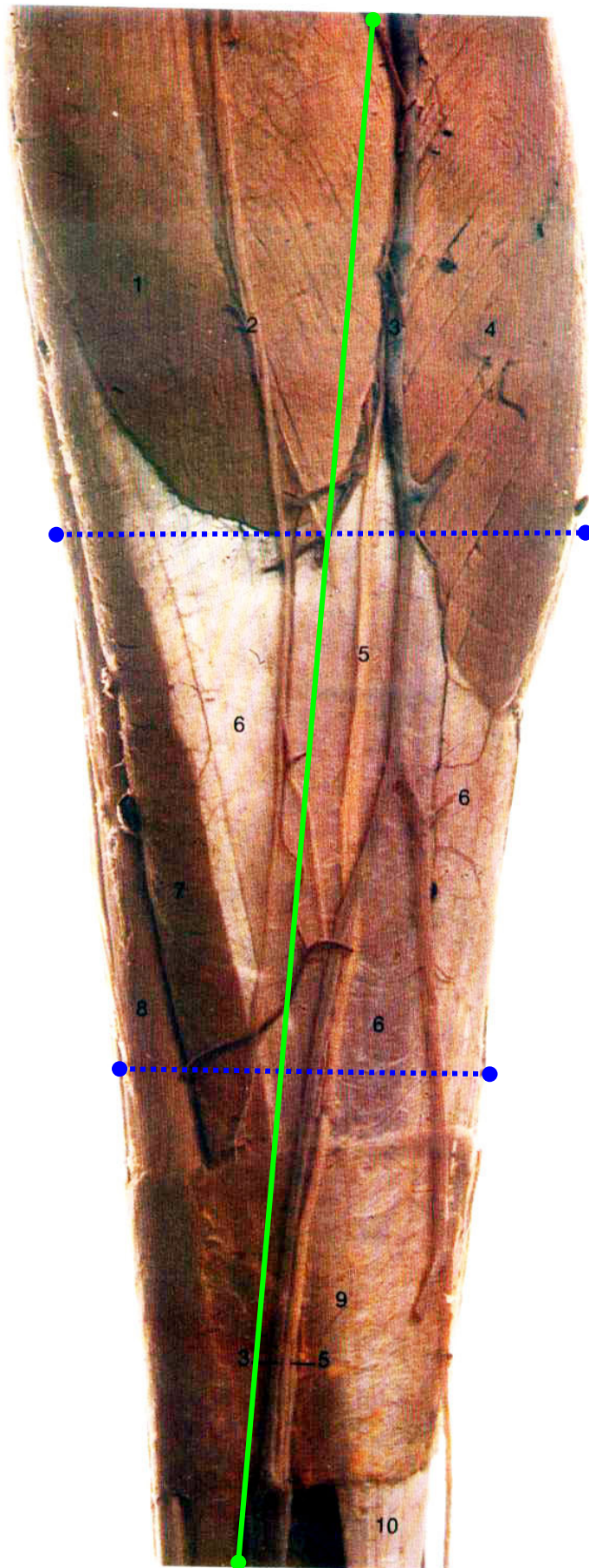
COURSE OF THE SURAL NERVE



CONVENTIONAL METHOD

A straight line is drawn connecting the midpoint of popliteal crease and the midpoint between the lateral border of TendoAchilles and tip of lateral malleolus representing the course of the sural nerve. Actually this line is 1-2 cms lateral to the original course of the sural nerve in the upper two thirds of the leg. Hence a flap positioned with the marked-line along its mid-axis tend to lie laterally i.e. the sural neurovascular bundle lies eccentrically and not in the mid-axis of the flap.

FLAP MARKING - CONVENTIONAL METHOD

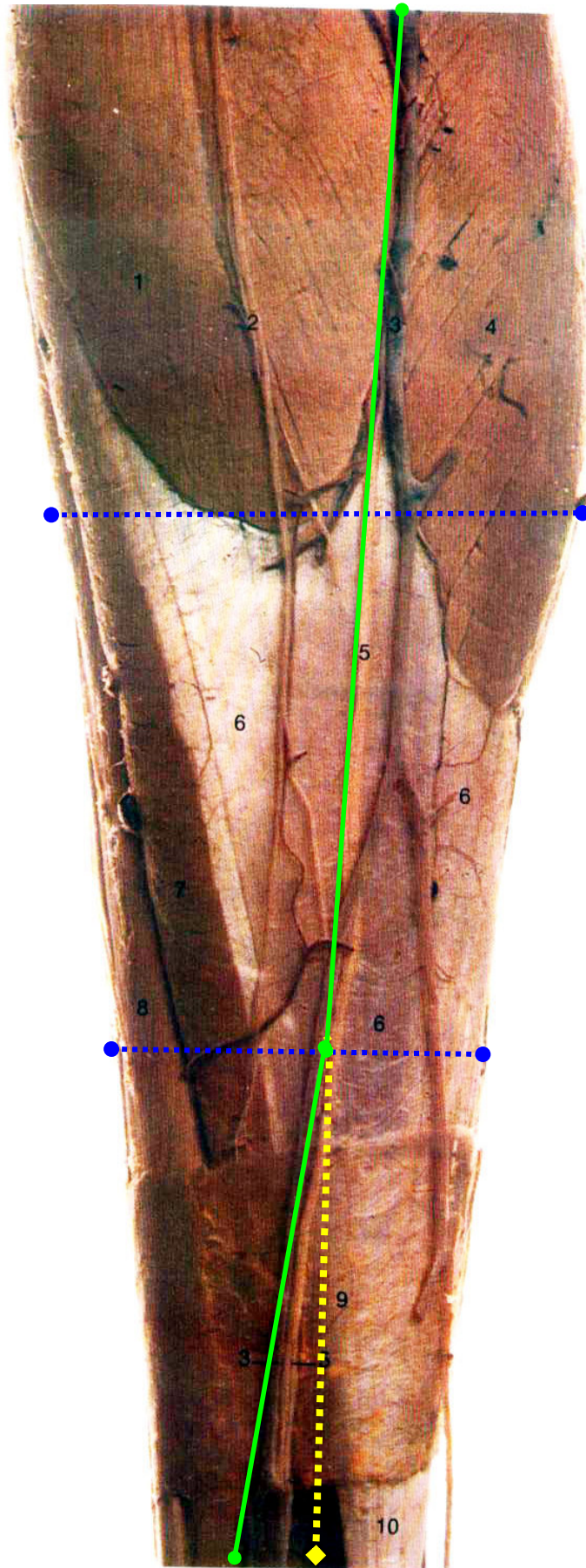


MODIFIED METHOD:

The distance between the mid point of the popliteal crease and the posterior midpoint of the inter-malleolar line is divided into three equal parts. A straight line is drawn in between these two points in the upper two thirds which lies in the posterior mid-line. Verify this by palpating the groove between the two bellies of the gastrocnemius muscle. A second straight line is drawn from the lower end of the first line at the junction of middle and lower thirds to the mid point between the tip of lateral malleolus and the lateral border of the TendoAchilles. Hence, the line is straight in the posterior midline in the upper two thirds of the leg and deflects laterally towards the lateral malleolus in the lower third.

This line represents the course of the sural nerve closely and hence in a flap positioned equally on either side of this line, the sural neurovascular bundle tend to lie almost in the mid-axis of the flap.

FLAP MARKING - MODIFIED METHOD



OPERATIVE TECHNIQUE

CONVENTIONAL METHOD:

The flap is approached with the patient in the prone position. A pneumatic tourniquet is used during flap elevation. Marking is initiated by identifying the distal aspect of the gastrocnemius muscles and the tendinous intersection between them. A line is then marked from a point halfway between the Achilles tendon and the lateral malleolus at the ankle extending to the midline between the two heads of the gastrocnemius muscle.

This roughly describes the course of the medial sural cutaneous nerve. After marking the path of the nerve, attention is focused on identifying the peroneal perforators that course through the posterior crural septum. The foot is dorsiflexed, demonstrating the interface between the musculature of lateral compartment and soleus muscle.

The Doppler probe is then used to identify and mark the peroneal perforators. Typically, four to five of these occupy a zone 5 to 13 cm above the tip of the lateral malleolus. Every effort is made to incorporate these perforators into the flap, which often determines the point of rotation. After identifying the lateral perforators, the lesser saphenous vein is identified and marked. Again, every effort is

made to incorporate this venous structure within the design of the flap. The skin island is then marked on the posterior calf and can be extended to a point of junction between upper and middle third of leg.

Designing the skin island in a teardrop-shape with the tail tapering distally will facilitate later closure after the flap inset. After marking the skin island, a decision is made regarding the base width of the flap, designed obliquely to the lateral malleolus to include the maximum number of lateral perforators.

The width of the pedicle must be 2 to 4 cm. Attention is now focused on elevating on the posterior calf, thin skin and subcutaneous tissue flaps. The dissection is initiated in the upper medial quadrant of the skin island. This is thought to be the safest zone to ascertain the proper plane of dissection.

The dissection is then continued around the distal aspect of the skin island for several centimeters. This is undertaken with a scalpel to prevent possible thermal cautery damage to these relatively thin skin and subcutaneous flaps. At this point sharp dissection is used to carry the dissection through the subcutaneous tissue and fascia of the superficial posterior compartment at the most distal aspect of the flap.

Here, the sural neurovascular bundle is encountered. The distal end is ligated, after which the median sural artery is divided. The blood flow from this vessel is typically gauged before its ligation. This may aid in future decisions regarding a possible delay of the flap. Tacking sutures are taken using 3-0 chromic catgut anchoring the deep fascia with the subdermal plane in order to facilitate the intactness of the blood vessels. The dissection then progresses quite rapidly, elevating the fascia off the gastrocnemius muscle.

The loose areolar tissue between the two heads of the gastrocnemius and its accompanying venous plexus is incorporated into the flap design. Attention is now refocused on completing the elevation of skin flaps over the posterior calf distal to the skin island. Here the flaps are elevated to a point several centimeters past the lateral muscular compartment. The dissection now proceeds rapidly from proximal to distal.

The several perforating arteries emanating from the gastrocnemius and soleus musculature are coagulated or ligated. At the midpoint of the gastrocnemius muscles, the sural nerve penetrates the deep scia. The neurovascular structures may be adherent at this point and incorporation of a small muscular cuff can help prevent damage. In addition, when elevating this flap in children

or positioning the skin island in close proximity to the popliteal fossa, one must be cognizant of the lateral sural cutaneous nerve.

This nerve emanates from the common peroneal nerve several centimeters distal to the fibular head. It may closely abut the lateral border of the flap, and it adjoins the medial sural cutaneous nerve by means of an intervening branch. Next, the dissection is continued distally to a point where the skin island easily rotates into the defect. A point 5 cm proximal to the tip of the lateral malleolus would represent the most distal point of safe flap elevation. The flap is then turned into the wound and sutured over penrose drains under minimal tension.

The skin edges around the defect are widely undermined to accommodate the subcutaneous tissues associated with the margins of the skin island. The donor site is then covered with a split-thickness skin graft. Sometimes if possible the donor area may be closed primarily. A full-leg posterior splint using foam padding has been successful in preventing pressure on the subcutaneous pedicle at the point of rotation. In post operative period patients are nursed in prone or lateral position for 3 to 5 days.

MODIFIED METHOD

Pre-operatively with the patient in prone position, the course of the sural nerve is marked as per the modified method. With Doppler probe, the peroneal artery perforators are marked in the lateral intermuscular septum and the course of short saphenous vein is also marked so as to include this along the axis of the pedicle. Pedicle length is measured from the distance between the lower most perforator and the proximal margin of the defect.

By reverse planning, the length and breadth of the flap required is measured and transposed after allowing adequate allowance for the pedicle length. Care is taken to mark the flap equally on both sides of the marked sural nerve position. The length of the flap extension into the upper third of the leg is measured.

Decision is also taken regarding islanding the flap, making a tear-drop extension or taking a 2cm width of skin all along the pedicle depending upon the length of the skin paddle between the base of the flap and the defect and the tightness of tunnel. The skin extension into the pedicle is appropriately marked. The breadth of the adiofascial pedicle should be 3-4 cms in width and oriented along the course of the sural nerve lower down to the peroneal perforator

on which the flap is based. The adipofascial pedicle should be gradually tapered from the transverse line corresponding to the maximum width of the flap and it is always safe to include the lateral intermuscular septum and short saphenous vein in the adipofascial pedicle.

Patient is approached in prone position under pneumatic tourniquet. The lateral half of the flap is incised first. Incision deepened and deep fascia incised and tagged to skin. Lateral half of the flap is raised in the subfacial loose-areolar plane by blunt dissection to identify the sural nerve where it pierces the deep fascia. This point corresponds to the junction of upper and middle thirds of the marked line. The course of the sural nerve in the subfascial plane is also compared with the pre-operative marking of the course of the nerve. If any minor discrepancy occurs then the medial incision of the flap is appropriately altered so as the position the sural nerve exactly lies in the centre of the flap. Care is taken to include the short-saphenous vein in the flap.

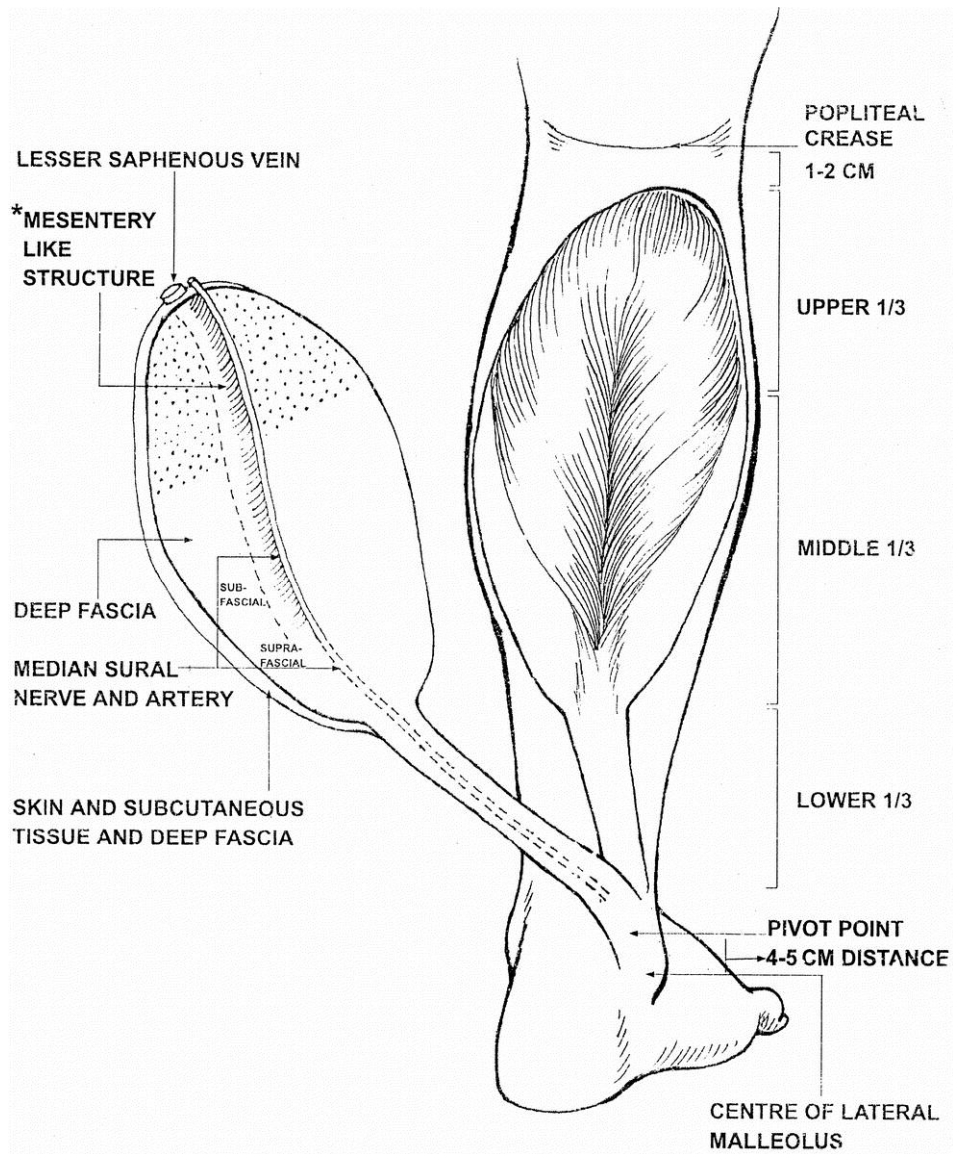
Now the medial half of the flap is incised and dissection done subfascially upto the midline. If the flap is limited to the middle third of leg then the sural nerve and median superficial sural vessels are

ligated and cut just proximal to its exit through the deep fascia and the flap raised.

Care is needed while elevating the extensions of the flap into the upper third of leg. After elevating the flap laterally and medially without cutting the sural nerve and median superficial sural vessels, which are now deep within the two bellies of gastrocnemius muscle, the flap is now attached only by this neurovascular pedicle. Start dissecting the neurovascular bundle proximally from its exit point into the deep fascia, taking care to include as much cuff of the mesentery - like tissue as possible deep to the pedicle between the gastrocnemius muscle bellies. Extreme care is needed to preserve the delicate vessels which run from this mesentery-like cuff of tissue to the deep fascia. On reaching the proximal end of the flap the sural neurovascular bundle is ligated and cut and tagged to the flap. Rest of the procedure is similar to the conventional method.

Depending on the intensity of bleeding from the cut distal end of sural neurovascular bundle and sub-dermal bleed from the proximal margin of the flap, decision is made whether to raise the flap in a single stage or to delay the flap.

OPERATIVE TECHNIQUE



Extended reverse sural artery flaps requiring delay is done in 3 stages. In the first stage the extension of the flap into the upper third of leg alone is dissected as described previously and the skin alone is sutured after ligating the sural neurovascular bundle. 7 days later, rest of the flap is elevated upto its base with as much width of adipofascial pedicle as possible and the flap is placed again in the same position and skin alone is sutured. 4-7 days later after assessing the survival of the flap, the patient is again taken to operation theatre and the flap is transposed to the defect and inset given. Immobilization and post-operative care are similar to that of conventional method.

OBSERVATION

In this study, a total number of 26 patients were included of which initial 13 cases were operated by conventional markings and method and the subsequent 13 cases were operated by modified method and markings.

SEX DISTRIBUTION:

In both groups male patients out numbered female patients.

TABLE NO.1

SEX DISTRIBUTION

	<i>Conventional Group</i>	<i>Modified Group</i>
Male	10	11
Female	3	2
Total	13	13

AGE INCIDENCE:

We came across patients in all age groups ranging from 10 years to 60 years who were included in the study.

TABLE - 2
AGE INCIDENCE

Age Group	Conventional Group		Modified Group	
	No. of cases	Percentage	No. of cases	Percentage
10-20 years	2	15%	2	15%
21-30 years	2	15%	3	23%
31-40 years	2	15%	4	31%
41-50 years	3	23%	1	8%
51-60 years	4	31%	3	23%

AETIOLOGY OF THE DEFECTS:

In this study, we came across various aeteologies like motor vehicle accidents, unstable scar excision, closet injury, post-excisional defect of skin malignancies and electrical burns. The majority of the cases were due to motor vehicle accidents.

TABLE NO.:3
AETIOLOGY OF DEFECTS

Causes	Conventional Group		Modified Group	
	No. of cases	Percentage	No. of cases	Percentage
Motor vehicle accidents	6	46%	8	62%
Unstable scar excision	2	15%	2	15%
Skin malignancy excision	2	15%	2	15%
Closet injury	1	8%	1	8%
Electrical Burns	1	8%	0	0%
Tibial osteomyelitis	1	8%	0	0%

REGIONS INVOLVED

In this study, we came across defects involving all the regions of the lower third of the leg, ankle and foot. In majority of the cases, two or more regions were involved.

**TABLE NO. 4:
REGIONS INVOLVED**

<i>Regions involved</i>	<i>Conventional Group</i>		<i>Modified Group</i>	
	<i>No. of cases</i>	<i>Percentage</i>	<i>No. of cases</i>	<i>Percentage</i>
Heel	4	31%	3	23%
Medial malleolus	3	23%	3	23%
Lateral malleolus	2	15%	1	8%
Tendo achilles	1	8%	2	15%
Proximal foot	2	15%	3	23%
Dorsum of foot	1	8%	1	8%

Out of 13 patients operated by conventional method, the flap was limited to the middle of third of leg in 2 cases. Remaining 11 cases, needed flap extension into upper third of leg ranging from 2cms to 13 cms. The smallest flap was 7x8 cms with a pedicle length of 26cms. The largest flap was 10x16cms with a pedicle length of 24cms.

In the 2 cases in which the flap was limited to the middle third of leg, there was no venous congestion or flap tip necrosis and both the flaps settled well. In the 10 cases which needed flap extension into the upper third of leg and elevated in a single stage, 2 cases developed venous congestion which settled subsequently and 5 cases developed distal tip necrosis which ranged from 1-3 cms. In the largest flap which was elevated in stages with a delay, distal tip necrosis of 4.5 cms occurred.

In the other 13 patients operated by the modified method, the flap was limited to the middle third of the leg in 2 patients. Remaining 11 patients needed flap extension into upper third of the leg ranging from 3-8.5 cms. The smallest flap was 6x8 cms with a pedicle length of 24 cms and the largest flap was 10x18 cms with a pedicle length of 26 cms.

In the 2 cases in which the flap was limited to the middle third of the leg, there were no complications and both flaps settled well. In 10 cases which needed flap extension into the upper third of the leg and elevated in a single stage, venous congestion developed in 2 cases which settled subsequently and healed uneventfully and one flap developed partial thickness flap tip necrosis of 1cms. In the largest flap in

this group which measured 10x18cms which was elevated in stages with a delay, distal tip necrosis of 2cms occurred.

Post-operative wound infection occurred totally in 2 cases, which was treated by conservative measures and which did not affect the survival of flap adversely.

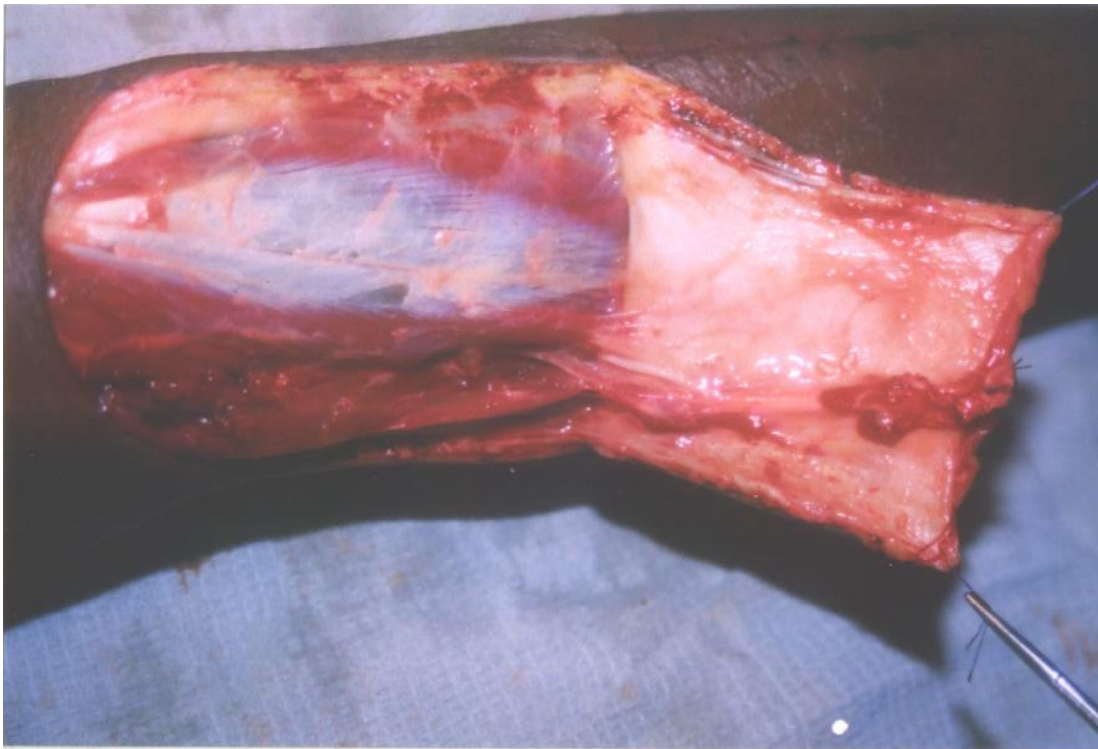
CONVENTIONAL METHOD - SINGLE STAGE



CONVENTIONAL METHOD - SINGLE STAGE



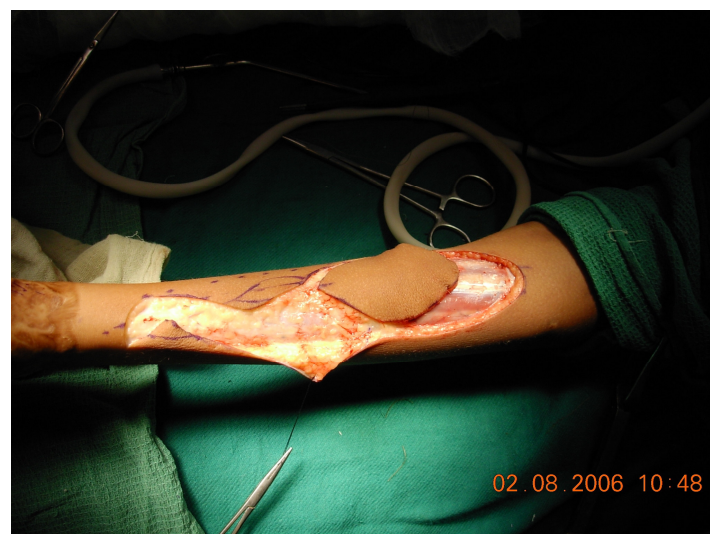
CONVENTIONAL METHOD WITH DELAY



CONVENTIONAL METHOD WITH DELAY



MODIFIED METHOD - SINGLE STAGE



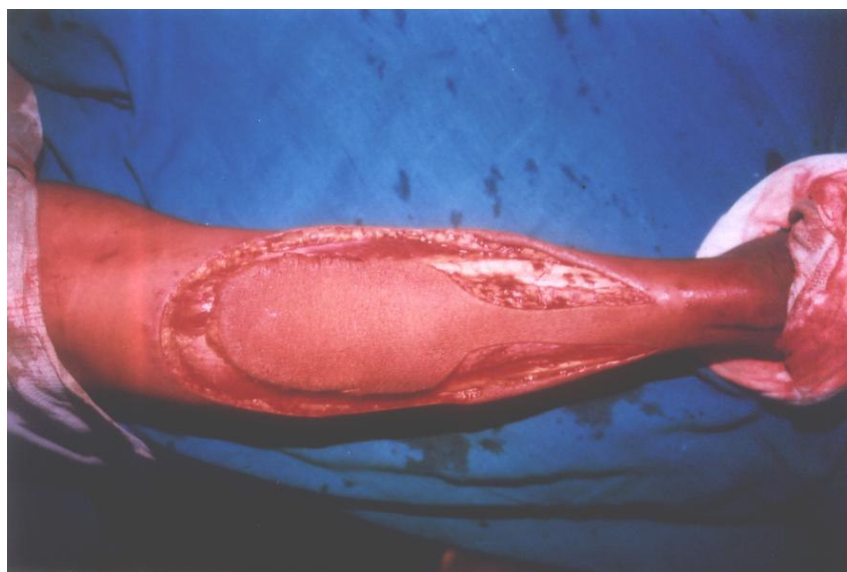
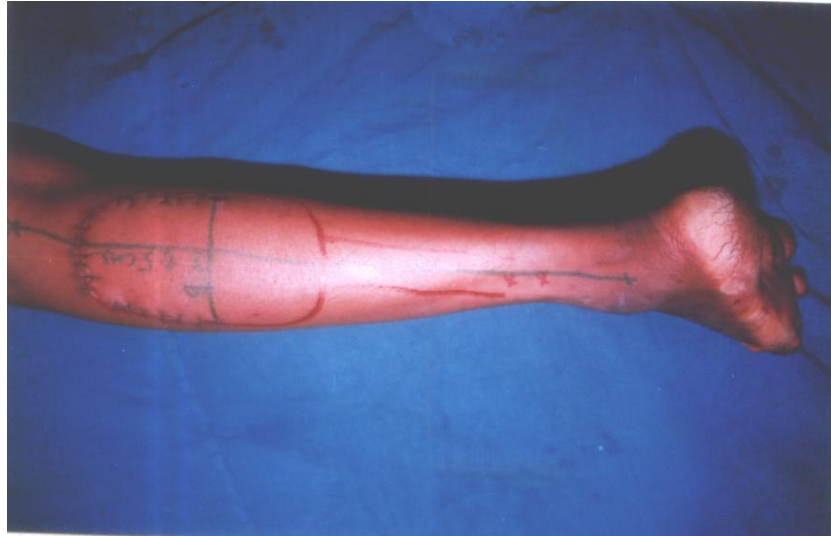
MODIFIED METHOD - SINGLE STAGE



MODIFIED METHOD - SINGLE STAGE



MODIFIED METHOD WITH DELAY



MODIFIED METHOD WITH DELAY



DISCUSSION

Reconstruction of defect on ankle, malleoli and heel remains difficult task for plastic surgeons. There are many possibilities for coverage of defects in these regions such as skin graft, cross leg flap, reversed muscle flap with skin graft, reversed fascial or adipo fascial flap with skin graft and reversed flaps using a major artery⁶. Coverage of wounds of the lower one third of the leg are usually best treated using microvascular free tissue transfer².

These flaps provide reliable single stage coverage of the wounds. There are, however disadvantages in using free flaps. Among these are the need for a remote donor site, increased operative time, use of major vessel to the leg and micro surgical expertise.

The alternative for coverage of these areas has been pedicled fascio cutaneous flaps as described by Ponten²⁴. Unfortunately, even when properly designed with perforators at the base of the flaps the distal most portion is often random in its blood supply”.

This can lead to marginal flap necrosis requiring additional procedures to achieve coverage. If microvascular surgical facility is not available, the ideal flap should be a reliable and one stage procedure that should not sacrifice a major artery or nerve.

In 1992 Masquelet et al 20 reported the blood supply to leg skin from the arteries accompanying the superficial peroneal, sural, saphenous nerves. These arteries give off several cutaneous branches in the supra fascial course. They described the concept of neurocutaneous flap. From a practical point of view neurocutaneous arteries are similar to direct cutaneous arteries and the flap designed on such a blood supply can be considered an axial pattern flap¹².

Few studies have illustrated clearly the vascular territory of the superficial sural artery and the vascular anastomoses between the superficial sural artery and the septocutaneous peroneal perforator. The vascular anastomoses between the superficial sural artery and the septocutaneous peroneal perforator were difficult to demonstrate by anatomic dissection because these terminal cutaneous branches and their vascular network are tenuous and damaged easily²⁶.

By current anatomic and angiographic study, the vascular territory of the superficial sural artery and the vascular anastomoses between the superficial sural artery and septocutaneous perforators from the peroneal artery are well demonstrated by the lead oxide injection technique¹².

The constant vascular anastomosis forms an arterial network around the course of the whole length of the sural nerve distally. The septocutaneous peroneal perforator can capture reliably the vascular territory of the superficial sural artery¹⁴. Therefore the septocutaneous peroneal perforators can supply a reverse flowflap.

Masquelet et al²⁰ reported the concept of neuroskin flap in 1992. Hasegawa et al¹³ later refined this technique. Yilmaz et al³⁰ modified the technique, but were uncertain as to how large a flap could be elevated successfully. The largest flap reported by Hasegawa et al¹³ had a width of 10 cm and a length of 13 cms. The authors noted that the edema lasted for 2 months. They voiced concern regarding serious venous congestion in larger flaps and suggested the use of smaller flaps.

Masquelet et al²⁰ also stated that, although reversed sural artery flaps have been used by many surgeons successfully, there are no studies about maximum flap dimensions and safety. Jeng & Wei¹⁶ suggested preservation of the sural nerve by using only the sural artery to vascularise the flap and stated that the flap could be elevated from any part of the sural region.

In 1998, Yilmaz et al³⁰ reported that the largest flap used in their series measured 15x12cms, which they claimed was the biggest flap till 1998. In 2002, Ayyappan et al⁴⁷ presented their series of 4 extended reverse sural flaps with the largest flap measuring 17x16 cms, far more than ever reported in literature. In our series, the largest flap was 10x18cms which had been raised with a delay and a distal necrosis of 2cms occurred after the delay.

In our initial series of 13 cases flaps were marked and raised by conventional method, we did not have any problem with the 2 flaps which were limited to the middle third of the leg. But with 10 cases of flap extension into the upper third of leg and done in a single stage we had venous congestion in 2 cases out of which one settled with conservative measures and the other one went in for distal necrosis of 1cm. We had distal necrosis ranging from 1-3 cms in other 4 cases also. We even had a distal flap necrosis of 4.5 cms in the 10x16cm sized flap which was raised in stages after delay.

We attribute the failure to two factors. First with the conventional marking of the course of sural nerve, which was significantly lateral to the original course of sural nerve in the upper two thirds of leg, and placing the flap with the sural nerve marking in the centre of the flap, the orientation of the sural neurovascular

bundle in the flap was to the medial side of the midline of the flap. This resulted in the flap being unequal on either sides of the sural neurovascular bundle.

Secondly, when we incised the superior end of the flap first and dissected for the sural neurovascular bundle which is deep within the two bellies of gastrocnemius in the upper third of the leg, there is considerable amount of shearing of the tip of the flap from the sural neurovascular bundle. The delicate mesentry-like tissue between the deep fascia of the tip of the flap and the sural neurovascular bundle was sheared-off in many of the cases in which the tips were necrosed.

These serendipitous findings provided the knowledge for the modified markings and the modified technique of flap raising in the subsequent 13 cases. With this technique there was absolutely no complications in 2 of the cases which were limited to the middle third of leg. In the other 10 cases which needed skin extensions ranging from 3 to 6 cms, and which were raised in a single stage we had venous congestion in 2 cases which settled with conservative measures in 2 weeks time.

Of these 2 cases, in one case the short saphenous vein was inadvertently injured while dissecting the lower end of the pedicle and in other there was an anomalous short saphenous vein which was not in the territory of the flap. We had a flap tip necrosis of 1 cm in another case, which we attribute it to the shearing of the sural neurovascular bundle from the tip of the flap.

In the largest flap in this group which measured 10x18 cms, which we decided to delay because of poor subdermal bleeding on table after raising the flap in the upper third of the leg, we had a 2cm tip necrosis after the second stage delay on one side, which we attribute it to the orientation of the flap to one side of the sural neurovascular bundle.

The venous congestion rate was 18.2% in both groups although which could have been avoided in the modified method group by including the short saphenous vein in the flap. The flap tip necrosis rate was 54.5% in the conventional group compared with 18.2% in the modified group which is significantly lower.

The lower flap tip necrosis rate in the modified group could be attributed to the two factors. Firstly, modified marking which places the flap equally on both sides of the sural neurovascular bundle most

of the times and even minor differences could be adjusted by the modified operative technique per-operatively by corresponding adjustment of the medial side of the flap.

Secondly, with the modified operative technique of dissecting the sural neurovascular bundle disto-proximally from its point of entry into the deep fascia, where it could easily be identified without much dissection, the delicate mesentry-like tissue connecting the sural neurovascular bundle and the deep fascia could be preserved right upto the tip of the flap without much shearing. This mesentry-like structure contains small perforator vessels that run into the deep fascia and possibly ramify with the fascial vascular plexus which accounts for the reliability of this distally based flap despite its huge dimensions.

In the study by Ayyappan et al (2002)⁴⁷, they reported 4 extended reverse sural flaps of huge dimensions of which 3 were elevated in a single stage and one with a delay. They had venous congestion and flap tip necrosis in one case which accounts to 25% although the number of cases is less.

In the study by Ulrich Kneser et al (2004), they reported 11 patients with extended reverse sural flap; with a single delay ranging from 7-15 days. The flap dimensions ranged from 9-19 cms in length and 7-12 cms in width. They experienced failure in 3 cases (27.3%). They recommend the delay procedure in patients with co-morbid conditions which would affect the flap adversely and if a two-stage approach of treatment of the underlying condition is anticipated, to increase the reliability of the extended reverse-sural flaps.

CONCLUSION

- Extended reverse superficial sural artery flaps are a versatile choice of reconstruction of difficult heel and foot defects.
- This flap replaces microsurgical reconstructions as a first choice in most cases of heel and foot defects with the added advantages of not sacrificing a major artery, a reduced time factor and a lower required level of expertise and infrastructure.
- The safety and reliability of the flap, despite its large dimensions, have been thoroughly verified in our experience.
- The dissection is simple, and the morbidity, in terms of loss of sensation of sural area, is minimal, the advantages for out weight the compromises.
- Doppler should be used not only to mark the perforators, but also to mark the course of the lesser saphenous vein for inclusion of this structure along the lie of the pedicle

which significantly reduces the venous congestion and increases the flap survival.

- The modified sural nerve marking and the modified and careful operative technique significantly reduces the flap tip necrosis rate and increases the reliability of the extended reverse sural flaps.
- For high-risk patients, whose underlying condition warrants a two-staged treatment approach, flap delay is a safer way to increase the reliability of the extended reverse superficial sural artery flaps.

PROFORMA

Name:

Age:

Sex:

Date:

Co-morbid illness:

Diagnosis/ Aetiology:

Area of defect:

Size of the defect (cms):

Markings & method: Conventional / Modified

Dimensions of the flap (cms):

Skin extension into upper third of leg (cms):

Single stage / multiple stages with delay:

Complications:

Follow up:

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PROFORMA

Name:

Age:

Sex:

Date:

Co-morbid illness:

Diagnosis/ Aetiology:

Area of defect:

Size of the defect (cms):

Markings & method: Conventional / Modified

Dimensions of the flap (cms):

Skin extension into upper third of leg (cms):

Single stage / multiple stages with delay:

Complications:

Follow up:

MASTER CHART

CONVENTIONAL METHOD

Patient No.	Age (yr/sex)	Diagnosis	Site of defect	Risk factors	Size of flap (cm) (skin peddle) (Width x length)/ Total length of flap	Skin extension into the upper 1/3 of leg (cm)	Complications
1.	38/M	Motor vehicle accident	Heel and medial malleolus	Nil	9x16/27	4 cms	Venous congestion with flap tip neocrosis - 2cms
2.	59/F	Malignant melanoma heel	Heel	Systemic hypertension	8x13/24	3 cms	Nil
3.	11/F	Motor vehicle accident	Proximal dorsum of foot	Nil	8x10/23	3cms	Infection
4.	41/M	Osteomyelitis of lower tibia	Lower third of leg-medial aspect	Diabetes mellitus	8x10/24	Nil	Nil
5.	27/M	Closet injury	Tendoachilles area and posterior heel	Nil	7x8/26	2cms	Nil

6.	44/M	Motor vehicle accident	Medial malleolus and proximal foot	Nil	9x15/26	4 cms	Flapt tip necrosis - 1cm
7.	52/M	Chronic instable scar	Heel	Systemic hypertension with CAD	9x14/25	3cms	Venous congestion
8.	30/M	Electrical burns	Heel	Nil	8x14/26	2cms	Flap tip necrosis -1cm
9.	60/M	Squamous cell carcinoma	Proximal foot-dorsum	Nil	8x10/25	Nil	Nil
10.	13/M	Motor vehicle accident	Lateral malleolus & proximal foot	Nil	9x13/24	4cms	Flap tip necrosis - 2cms
11.	35/F	Motor vehicle accident	Heel & lateral mallcolar area	Nil	8x13/26	3cms	Venous congestion
12.	41/M	Unstable scar	Medial malleolus & sole of foot	Nil	10x14/24	5cms	Flap tip necrosis -3cms
13.	54/M	Motor vehicle accident	Dorsum of foot	CAD	10x16/24	13 cms delay done	Flap tip necrosis 4.5cms
MODIFIED METHOD							
14.	40/M	Motor vehicle accident	Medial malleolus & proximal medial foot	Nil	9x14 cms/24	3cms	Infection

15.	52/M	Chronic unstable scar	Heel	Diabetes mellitus	8x15/22	4cms	None
16.	13/F	Motor vehicle accident	Lateral malleous and proximal foot	Nil	9x13/24	4cms	None
17.	60/M	Malignant melanoma	Heel & lat. Border of foot	Systemic hypertension	9x14/26	5cms	Venous congestion
18.	32/M	Unstable scar	Lower third leg, medial malleolus and proximal foot	Nil	10x15/24	6cms	None
19.	22/M	Motor vehicle accident	Proximal & mid dorsum of foot	Nil	10x14/25	4cms	Venous congestion
20.	30/F	Dermatofibro sarcoma protruberans	Lower third leg-medial aspect and medial melleolus	Nil	8x13/22	Nil	None
21.	41/M	Chest injury	Tendo achilles & posterior heel	Nil	8x10/22	3cms	None
22.	27/M	Motor vehicle accident	Lateral malleolus & heel	Nil	9x14/24	5cms	Flap tip partial thickness necrosis - 1cm
23.	57/M	Motor vehicle accident	Medial malleolus & proximal foot	Nil	8x12/24	3cms	None

24.	12/M	Spokes wheel injury	Tendoachilles region	Nil	6x8 cms/24	Nil	None
25.	35/M	Motor vehicle accident	Medial malleolus & proximal sole of foot	Nil	9x16/24	5cm	None
26.	37/M	Motor vehicle accident	Whole dorsum of foot	Nil	10x18cm/26	8.5cms delay done	Lateral tip necrosis - 2cms after delay